WET SNOW IN THE NORTHWEST

Summary prepared by Mark Moore, NWAC—updated 6/30/03

FORMATION

1) Radiation

a) Short wave (incoming solar)
   i) Albedo/reflectivity ranges from 75-95% for new snow—dependent on density (almost 100% measured at high elevations for newly fallen snow
   ii) Albedo/reflectivity ranges from 40-65% for old, wet snow (40% for dirty firn, glacier ice to 60-65% for wet snow)—wetness increases albedo significantly—a good feedback mechanism
b) Long wave (re-radiation from snow and clouds)
   i) Snow acts like a black body and absorbs almost 100% of incoming long wave (re-radiated from clouds)
c) Greenhouse effect from clouds
   i) Long-wave radiation from earth/snow surface is absorbed and re-radiated by clouds as long-wave radiation

2) Warm temperatures

a) Sensible heat—conduction from warm air in contact with the snow surface

3) Stored energy of warm moist air—Latent heat of vaporization

a) Condensation of warm, moist air on the colder snow surface releases the latent heat of condensation. Water vapor condensing onto the snow surface releases the latent heat of condensation or vaporization of ~600cal/gm—about 10 times more effective in snowmelt than warm rain.

4) Rain

a) Warm rainfall adds both heat and free water to the snowpack
b) However, rain only adds the latent heat of melting or fusion to the snowpack or about 80 cal/gm—so much less effective in melting than if a warm moist air mass flows over the snowpack and releases the latent heat of condensation

In the spring, warming of the snowpack occurs both from below (heat transfer from the warmer ground) and from the surface (warm air, rain, etc). This warming can be enhanced near rocks or trees that both retain heat and transfer it to the snowpack. Also, the effects of a snowpack becoming weak and isothermal (at 0 deg C) may be enhanced in steeper terrain where the snowpack may be shallow, and over smooth rock faces that may focus melt water and produce glide cracks. These glide cracks, which indicate shear failure of the overlying slab, mean that the slab is now held in place primarily by flank and compressive anchoring, as it has lost its tensile strength or attachment at the top of the slab. Such slopes may fail during conditions that encourage melt and rates of free water transfer into the snowpack.

Wind can greatly affect the transfer of heat into the snowpack and associated melt rates of near surface snow. During moderate to strong winds, the moistening near surface air in contact with the snow is constantly mixed with drier air above through turbulence. As a result the air is continually drying out and enhances evaporation from the snow surface rather than melt. Heat loss from the snow necessary to drive the process cools off near surface snow and results in substantially less melt than otherwise might occur, even if temperatures are well above freezing. However, melt water production may still continue and thrive in wind sheltered (and directly sun exposed terrain).

In a maritime climate where wind direction greatly influences the humidity of the air mass—east winds bring relatively dry air across the snow surface while west winds bring much moisture air from the ocean—the snowmelt process can be greatly enhanced by warm moist west winds. This effect may be maximum during conditions of shallow stratus decks or thin upslope clouds which trap radiation (re-radiate in the long wavelength spectrum) and allow for condensation of moist air directly onto the snow surface, adding the latent heat of condensation (600 cal/gm) to the snowpack. Conversely, drier easterly flows may enhance evaporation, which takes heat from the snowpack.

Once the **snow surface is wet** by whatever process, the albedo of the snow surface drops dramatically…a self perpetuating process which may often only be slowed through wind effects or sunset.

Once some unevenness of the snow surface develops in the spring, a wind may dramatically help the formation of sun cups. Once the unevenness exists, air flow across the peaks favors evaporation from the peaks, while calmer air in the valleys favors condensation onto the snow surface and conduction related melt. Once the snow surface is wet, this drops the albedo further, and then the melting process really takes off, so that the valleys deepen (favoring calmer air and more heat transfer), while near the peaks more evaporation occurs so that the differential between peaks and valleys increases. However, a warm wet storm can quickly flatten the peaks (and the snowpack's surface) as their preferential exposure to the storm (larger surface area exposed to warm air, rain or condensation) hastens their melt over the sheltered valleys.

WET SNOW and SPRING AVALANCHING

Triggers for wet snow avalanches

1) **Rain**
   a) Adds weight but no strength, warms the snowpack, percolates downward through the snowpack (via flow fingers) and may weaken progressively deeper snow layers—pooling in lower density layers (higher capillary pressure) or just above ice lenses or rain crusts. These flow fingers, once established, help route free water out of near surface snow and when frozen, act as spikes into the snow and anchor it effectively.
2) **Rising freezing levels and warm temperatures**
   a) Watch for rapid rises in temps and freezing levels after storms
   b) Consider increasing clouds and greenhouse effect, especially overnight after prolonged warming event
3) **Solar radiation**
   a) Begins on east and southeast exposures in morning
   b) Ends on west and southwest exposures in the afternoon
4) **Non-homogeneous snowpack layering**
   a) Preferential free water retention near crusts and fine-grained snow due to blocking of the flow (crusts and lenses) or capillary pressure (fine grained snow)
   b) Resultant saturation and weakening of snow
5) **Wind effects**
   a) In the absence of local pressure gradient or free winds—
      i) Down slope winds overnight will normally help cool and refreeze snow
         (1) Winds blowing downslope over snow will cool through conduction and convection currents next to snow surface—which is losing heat due to evaporation of meltwater and sublimation directly from solid snow surface to vapor phase
      ii) Upslope winds in morning will warm and melt snow through conduction as they bring warmer air from lower elevations that are often snow free
   b) General wind increase—causes heat that would ordinarily go into snow melt and free water production to be lost to the atmosphere through evaporation and sublimation of free water and near surface snow
   c) Other factors being equal, given a warm above freezing air mass, light or no winds normally enhance melt water production. Air near the snow surface becomes saturated, allows little or no further heat loss due to evaporation and focuses heat into melting of the surface snow.

HEAT FACTS

- Latent heat of melting/fusion = 80 cal/gm
- Latent heat of evaporation/condensation = 600 cal/gm
- Latent heat of sublimation or vapor deposition = 680 cal/gm

Snow albedo (percentage of short wave radiation reflected) decreases significantly with increasing density (95 down to 75%), and more so with age and wetness (ranging from over 80% for new snow to less than 50% for 20 day old snow. However the greatest decrease with age of snow occurs in the first few days. The amount of long wave radiation reaching a particular snow surface may be strongly influenced by surrounding topography, and a bowl shaped slope may become a true broiler with a maximum of heat flux into the snowpack as a result of both reflected and retransmitted radiation from surrounding slopes. Also, rain falling on a below freezing snowpack may quickly change the thermal regime of near surface snow—consider this: 10mm of rain at 0 deg C uniformly distributed in a 1-m snowpack with a density of 340kg/m3 would, on refreezing (through releasing the latent heat of fusion), raise the average temperature of the snowpack from –5 to 0 deg C.